

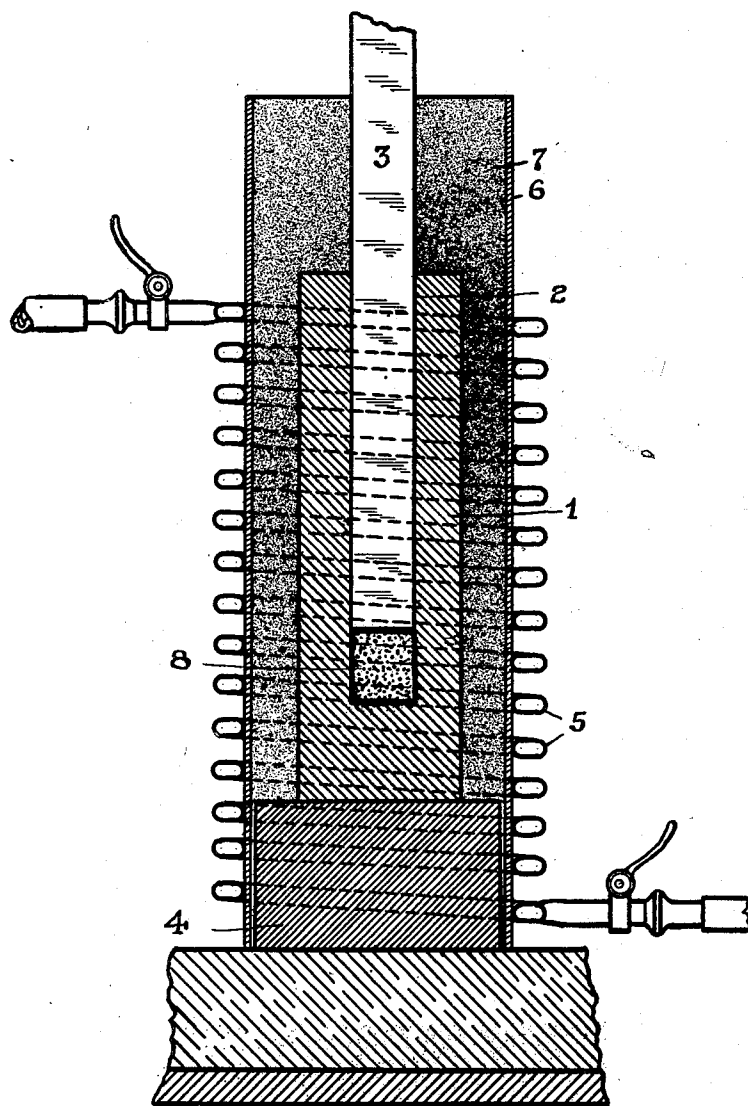
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COMPOSITION OF MATTER FOR STEEL CUTTING TOOLS, DRAWING DIES AND THE LIKE

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COMPOSITION OF MATTER FOR STEEL
CUTTING TOOLS, DRAWING DIES, AND
THE LIKE

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This invention consists of an improved hard composition of matter intended for use as a steel cutting tool and for like purposes.

In the production of a hard composition for these purposes I have used a material wherein the particles are in welded relation to each other and which comprises tantalum carbide and tungsten metal.

In the process for the production of such material which is the subject matter of my pending application Serial No. 491,734 filed in the United States Patent Office October 28, 1930, which has become Patent No. 1,892,653, I produced a hard composition by treating a mixture of tungsten carbide and tantalum, W_2C and Ta, as therein described. But by this method the percentage of tantalum carbide in the finished product is limited to approximately 30% because of the proportion of W_2C which is necessary to use to effectually carburize the tantalum. Again to insure the carburization of the entire tantalum content an excess of W_2C is usually employed with the result that there exists in the composition a small W_2C content which is not considered desirable.

In my pending patent application Serial No. 491,735, filed in the United States Patent Office October 28, 1930, which has become Patent No. 1,848,899, I disclose another method of forming a tantalum carbide tungsten metal composition wherein the ingredients used are tantalum carbide and tungsten. By this method I am able to increase the percentage of tantalum carbide in the composition, but difficulty is sometimes encountered in securing a satisfactory welded union between the particles owing probably to the adsorbed gases which characterize the surfaces of commercial tungsten metal.

In my present invention I employ as the ingredients of my composition tantalum carbide, tungsten carbide and zirconium metal. These ingredients are in finely powdered form and are thoroughly mixed together. The mixture is then formed into a hard composition wherein the particles are in welded relation with each other, and this I effect by subjecting the mixture to pressure and high frequency eddy currents of sufficient voltage and alternations per second to effect a welding action between the particles together with a chemical reaction as hereinafter described.

The temperatures involved have as their lower limit a temperature sufficient to expedite the reaction desired within a commercially reasonable time. Thus approximately 1200° C. may be considered the low temperature limit for commercial

practice. The high temperature limit is determined by the critical temperature at which tungsten reacts with tantalum carbide containing some zirconium carbide to form tungsten carbide and to destroy the necessary tantalum carbide. This temperature in the case of pure tantalum carbide is approximately 2227° C. but I have found that critical temperature is several hundred degrees higher when the tantalum carbide phase contains zirconium carbide and that the high limit of temperature is therefore raised without danger of causing the destruction of the tantalum carbide phase. Thus I have used temperatures up to approximately 2500° C. The pressure should not be less than approximately 2000 pounds per square inch and not more than the crushing strength of the mold used. In the case of carbon and graphite molds this crushing strength is approximately 4000 pounds per square inch. A pressure below 2000 pounds per square inch does not effect a snug surface contact between the particles necessary to produce a mechanically strong welded union between said particles.

The term "phase" is used herein in its accepted sense in relation to chemistry and metallurgy, to wit—as indicating a homogeneous portion physically distinct from other portions by its bounding surfaces.

The tungsten phase is one consisting essentially of tungsten and showing under X-ray analysis a body-centered cubic lattice with a unit cell of approximately 3.155 Angstrom units, and this dimension may be altered in direct ratio by the addition of elements of different cubic dimensions but without showing a new series of diffraction lines.

A tantalum carbide phase is one consisting essentially of tantalum carbide and showing under X-ray analysis a sodium-chloride type lattice of from 4.49 to 4.30 Angstrom units, which may be altered in size in direct ratio by the addition of substances which do not show a different lattice, but merely change the dimension of the old one.

It is obvious that the amount of pressure required depends on the mass of the composition being formed. A small or thin piece of composition obviously requires less pressure.

The proportion of tantalum carbide used is determined by the proportion desired in the finished composition, an increase in the proportion of tantalum carbide causing greater resistance to abrasion or wear, the limit being the necessity for a sufficient proportion of tungsten to

provide the necessary shock resistance. Sufficient zirconium is added to the mixture to combine with the carbon of the tungsten carbide forming zirconium carbide and nascent tungsten metal free from adsorbed gases.

Thus when the composition is subjected to pressure and high frequency eddy currents the tungsten particles are readily and effectively welded to the tantalum carbide particles both being characterized by a cubic lattice and no adsorbed gases being present to interfere with the welding action. Moreover the zirconium carbide forms a solid solution with the tantalum carbide, without changing the cubic crystalline character of the lattice of the tantalum carbide and without forming a new phase.

All the lines of an X-ray spectrogram of a composition formed from 58.8% tantalum carbide, 29.4% W_2C and 11.8% Zr were completely accounted for by the body centered cubic lattice of tungsten of 3.15 (6) Angstrom units, and a cubic lattice of 4.37 Angstrom units, of the tantalum carbide, showing that the zirconium carbide was completely combined in solid solution with the tantalum carbide; and further demonstrating the absence of tungsten carbide, which is characterized by a hexagonal lattice and would have resulted in a non-isocrystalline form.

Tests have shown that a composition of this character has improved steel-cutting properties which may be due to the increased hardness of the tantalum carbide phase and also to the fact that the tungsten metal is nascent due to the formation of said metal from its carbide during the process of the manufacture of the composition.

The proportion of tantalum carbide in the mixture when the foregoing process is employed in manufacturing my improved composition may vary from 20% to 85% by weight, the balance being tungsten carbide and zirconium metal in relative proportions so that the zirconium is present in sufficient amount to decarburize the tungsten carbide, forming nascent tungsten metal and zirconium carbide which forms a solid solution with tantalum carbide.

Where pure zirconium is obtainable the proportion of zirconium to tungsten carbide necessary to form nascent tungsten metal is approximately 24% of the tungsten carbide, but as pure zirconium metal is difficult to obtain, my practice is to add an excess of Zr to ensure its proper functioning, the excess of zirconium, if any, remaining uncarburized, forming a solid solution with the tungsten, without changing its characteristic lattice.

In the finished product the percentage of the tantalum carbide phase is increased over the percentage of the tantalum carbide in the ingredients because of the addition thereto, in solid solution, of zirconium carbide. Thus where the proportion of tantalum carbide was 20% of the ingredients the percentage of the tantalum carbide phase in the composition would be approximately 37.7%, and where the proportion of the tantalum carbide in the ingredients was 85% the percentage of the tantalum carbide phase in the composition would be approximately 89.4%.

Thus for example, in the instance given above the zirconium used was not absolutely pure and I therefore increased the proportion to 40% of the tungsten carbide, providing for an excess to ensure the complete decarburization of the tungsten carbide.

I have accomplished another purpose in pro-

ducing my composition of tantalum carbide and tungsten metal by the use of zirconium metal and tungsten carbide to form the tungsten, for the resultant composition is more impermeable to the diffusion of carbon from the mold, than in cases where my composition is prepared directly by heating tantalum carbide and tungsten metal. It can be heated for a longer time without taking up any carbon. I find that I can employ higher temperatures than I am able to use where the ingredients are tantalum carbide and tungsten metal and thus the process is facilitated. This is due to the fact that the tantalum carbide phase when containing zirconium carbide is stable towards tungsten at a higher temperature than is pure tantalum carbide.

Sulphur, however, causes my composition to crack; apparently forming sulphide of zirconium, and small amounts of sulphur, sometimes contained in carbon, are harmful; on this account I prefer to use graphite instead of commercial carbon for my mold when using this zirconium process.

The conditions of temperature of about 2000° C., 4000 pounds per square inch pressure, and 25 high frequency eddy currents of 30,000 alternations per second may be obtained as follows.

A coil of flattened $\frac{1}{4}$ " copper pipe is wound around a $4\frac{1}{8}$ " inside diameter, making 26 turns with the succeeding layers of the copper coil separated by a space of $\frac{1}{8}$ ". The coil is shelled and suitable connections made at the ends by which water may flow through the center of the copper pipe which is not flattened sufficiently to impede the flow; also electrical connections are made at either end of the coil. A fused silica tube $4\frac{1}{8}$ " outside diameter and about 13" long with wall thickness of about $\frac{1}{8}$ " is placed in the copper coil and a refractory block about $\frac{3}{4}$ " in diameter and 2" thick is inserted at the bottom of the silica tube, resting on a substantial stone block supported by steel plates. A $2\frac{1}{2}$ " cylinder of graphite 8" long is cut out, with a hole of the cross-section desired in the bit of hard metal. The mixture of finely divided tungsten carbide, zirconium metal, and tantalum carbide is inserted in the hole in sufficient quantity so that the resultant bit of hard metal is of the desired size calculating from the specific gravity of the expected product. A ram also graphite is fitted into the hole and a screw arranged above the ram so that a pressure of 4000 pounds per square inch may be applied by hand. The high frequency eddy currents of electricity may be obtained from a transformer and condensers of sufficient capacity. The graphite mold is insulated from the silica tube by surrounding it with carbon black.

In the accompanying drawing wherein the apparatus is illustrated in vertical section, 1 represents the mold; 2 the hole bored therein; 3 the ram, 4 the refractory block upon which the mold rests; 5 the coil, 6 the fused silica tube in which the mold assembly is packed in the carbon black insulation 7, and 8 is the material to be treated.

The induced eddy currents at the rate of 5 kilovolt amperes are applied and continued to heat the particles. I have continued this step for approximately thirty-five minutes. Then pressure is applied to the ram and said pressure is gradually increased to the maximum which is limited by the crushing strength of the mold used, which strength in the case of graphite molds is approximately 4000 pounds per square inch. At the expiration of the period necessary to effect the desired reaction and the welding

operation, the application of current and pressure is discontinued and the mold removed from the carbon black and allowed to cool. The period of maximum pressure is usually about five minutes but such application may be prolonged until the proper welded relation between the particles is obtained.

The purpose of delaying the application of pressure until the particles have been properly heated is to permit the gasification and escape of any impurities which may be present with the ingredients, such, for instance, as sodium silicate.

On breaking the graphite mold the metal product is found to be of great density, absolute uniformity and capable of taking a keen and lipped edge on a silicon carbide grinding wheel.

Also molybdenum may replace the tungsten in part or in whole. Such substitutions are to be understood to be included within the scope of the appended claims.

Where columbium carbide is substituted for tantalum carbide, using similar atomic or molecular percentages, the ratio being approximately tantalum carbide 193.5 to columbium carbide 105.1, the columbium carbide would form approximately from 10.8% to 46.2% of the mass by weight of my improved composition.

Where hafnium is substituted for zirconium as an ingredient for my improved composition, using similar atomic percentages, the ratio being approximately zirconium 91 to hafnium 178.6, the hafnium would be added to the ingredients from which my composition is formed in the amount of 47.0% to 78.5% of the tungsten carbide.

Where molybdenum carbide is substituted for tungsten carbide, using similar atomic or molecular percentages, 204 parts of molybdenum carbide (Mo_2C) would be substituted for 380 parts of tungsten carbide (W_2C).

If the zirconium be added as an initial ingredient in the amount of from 24% to 40% by weight of the tungsten carbide, then in the finished composition, after the zirconium has decarburized the tungsten, the zirconium carbide will be present in the amount of from 28.0% to 46.7% of the tungsten. This is due to the fact that the atomic weight of the zirconium is 91 compared to the molecular weight of zirconium carbide which is 103 while the molecular weight of W_2C is 380 and 2W is 368.

Tungsten carbide (W_2C) has a molecular weight of 380 compared to the atomic weight of 2W, which is 368. The equation is $\text{Zr} + \text{W}_2\text{C} = \text{ZrC} + 2\text{W}$.

Likewise in the case of hafnium, where as an initial ingredient it is present in from 47.4% to 73% of the tungsten carbide, in the finished composition the hafnium carbide would be present in the amount of from 51.7% to 86.3% of the tungsten metal.

I have prepared my steel-cutting composition from 100 gms. W_2C , 40 gms. commercial zirconium metal powder, 200 gms. tantalum carbide in which case the Rockwell A hardness was 92½. Also by using 200 gms. W_2C , 80 gms. zirconium metal powder and 200 gms. TaC, I produced a very strong metal composition of 90½ Rockwell A. The tantalum carbide had been prepared from heating tantalum pentoxide with 20% of its weight of carbon black at about 1900° C., in a pure graphite crucible, covered, but with vents for the escape of the CO gas. The ingredients all in the form of powder were ground in a steel ball mill for 24 to 48 hours. I have found it advantageous to use the once formed composition

as part of the mix, by breaking it into 60 mesh pieces and re-grinding it up very fine in a ball mill, obtaining in this way a better particle size distribution and producing stronger compositions than when the particles are all of about equal size. My composition may contain from 20% TaC to 85% TaC with corresponding balance of tungsten and zirconium carbide.

Plates of my hard composition may be suitably attached to steel shanks forming steel-cutting lathe tools. These tools will cut steel of a hardness of 512 Brinell at speeds above 100 feet per minute without loss of edge, cutting over long periods of time, performing on steel-cutting jobs much better than any tool material ever produced, for example better than the tool material formed by cementing tungsten carbide with cobalt, which while satisfactory for cutting cast iron "craters" out rapidly in steel cutting.

I can obtain my improved composition by substituting tungsten metal, or a tungsten metal phase, for the tungsten carbide which is to be subsequently converted to tungsten by reaction with the zirconium. In such case the zirconium carbide may be initially added as such.

Preferably I may produce the zirconium carbide in solid solution in the tantalum carbide phase by the reduction of co-precipitated $\text{Ta}_2\text{O}_5 + \text{ZrO}_2$ with carbon. By using this latter method I am able to increase the amount of the tungsten metal phase in the composition and may indeed increase the tungsten metal in the product to any desired percentage. Theoretically the tungsten phase might be increased to approaching 100%, but a composition containing more than approximately 80% of tungsten metal would be lacking in wearing qualities in steel cutting tools.

What I claim is:—

1. A hard unmelted composition for steel-cutting tools, dies and the like, wherein the particles are in welded relation, and consisting substantially of tantalum carbide, tungsten metal and the carbide of one or more metals of a group consisting of zirconium and hafnium, the tantalum carbide forming from 20% to 85% of the mass by weight, and the metal or metals of the group consisting of zirconium and hafnium being present as an initial ingredient in a stoichiometrical sufficiency to produce the tungsten metal from tungsten carbide during the formation of the composition.

2. A hard unmelted composition for steel-cutting tools, dies and the like, wherein the particles are in welded relation, and consisting substantially of tantalum carbide, tungsten metal and the carbide of one or more metals of a group consisting of zirconium and hafnium, the tantalum carbide forming from 20% to 85% of the mass by weight, the metal or metals of the group consisting of zirconium and hafnium being added as an initial ingredient of the composition in a stoichiometrical sufficiency to produce the tungsten metal in the final composition from tungsten carbide during the formation of the composition.

3. A hard unmelted composition for steel-cutting tools, dies and the like, wherein the particles are in welded relation and consisting substantially of tantalum carbide, tungsten metal and zirconium carbide, the tantalum carbide forming from 20% to 85% of the mass by weight and the zirconium metal which is carburized during the formation of the composition being added as an initial ingredient in a stoichiometrical sufficiency

to produce tungsten metal from tungsten carbide during the formation of the composition.

4. A hard unmelted composition for steel-cutting tools, dies and the like, wherein the particles are in welded relation and consisting substantially of tantalum carbide, tungsten metal and hafnium carbide, the tantalum carbide forming from 20% to 85% of the mass by weight and the hafnium metal which is carburized during the formation of the composition being added as an initial ingredient in a stoichiometrical sufficiency to produce tungsten metal from tungsten carbide during the formation of the composition.

5. A hard unmelted composition for steel-cutting tools, dies and the like, wherein the particles are in welded relation and consisting substantially of tantalum carbide, tungsten metal and zirconium carbide, the tantalum carbide forming from 20% to 85% of the mass by weight and the zirconium carbide containing sufficient zirconium to produce the tungsten metal from tungsten carbide during the formation of the composition.

6. A hard unmelted composition for steel-cutting tools, dies and the like, wherein the particles are in welded relation and consisting substantially of tantalum carbide, tungsten metal and zirconium carbide, the tantalum carbide forming from 20% to 85% of the mass by weight, the tungsten being present as an initial ingredient of the composition in the form of tungsten carbide and the zirconium being present as an ingredient in the amount of from 24% to 40% by weight of the tungsten carbide.

7. A hard unmelted composition for steel-cutting tools, dies and the like, wherein the particles are in welded relation and consisting substantially of tantalum carbide, tungsten metal and hafnium carbide, the tantalum carbide forming from 20% to 85% of the mass by weight, and the hafnium carbide containing sufficient hafnium to produce the tungsten metal from tungsten carbide during the formation of the composition.

8. A hard unmelted composition for steel-cutting tools, dies and the like, wherein the particles are in welded relation and consisting substantially of tantalum carbide, tungsten metal and

hafnium carbide, the tantalum carbide forming from 20% to 85% of the mass by weight, the tungsten being present as an initial ingredient of the composition in the form of tungsten carbide and the hafnium being present as an initial ingredient in the amount of 47.0% to 78.5% by weight of the tungsten carbide.

9. A hard unmelted composition for steel-cutting tools, dies and the like, wherein the particles are in welded relation and consisting substantially of tantalum carbide, tungsten metal and zirconium carbide, the tantalum carbide forming from 20% to 85% of the mass by weight and the zirconium carbide being present in the amount equalling from 28.0% to 46.7% of the tungsten metal.

10. A hard unmelted composition for steel-cutting tools, dies and the like, wherein the particles are in welded relation and consisting substantially of tantalum carbide, tungsten metal and hafnium carbide, the tantalum carbide forming from 20% to 85% of the mass by weight and the hafnium carbide being present in the amount equalling from 51.7% to 86.3% of the tungsten metal.

11. A hard composition for steel-cutting tools, dies and the like, wherein the particles are in welded relation and consisting substantially of columbium carbide forming from 10.8% to 46.2% of the mass by weight, tungsten metal as a binder for such carbide and a stoichiometrical sufficiency of a metal or metals of a group consisting of zirconium and hafnium to produce the tungsten metal from tungsten carbide during the formation of the composition.

12. A hard composition for steel-cutting tools, dies and the like, wherein the particles are in welded relation and consisting substantially of columbium carbide forming from 10.8% to 46.2% of the mass by weight, molybdenum metal as a binder for such carbide and a stoichiometrical sufficiency of a metal or metals of a group consisting of zirconium and hafnium to produce the molybdenum metal from molybdenum carbide during the formation of the composition.

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